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# Do the regional growth effects of air transport differ among airports?

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A B S T R A C T

This paper empirically studies the contribution of air transport to regional economic development in Germany. We find that the scale and direction of output effects of air services and airport infrastructure differ among airports. These differences are driven by 'opportunity costs' of airport capital and by positive output effects from air transport connectivity. We argue that the latter impacts potentially depend on traffic characteristics.



## 1. Introduction

The possibility to use transportation infrastructure and transportation services widens opportunities for interaction. An economy may benefit from these opportunities for interaction by growing its output (Lakshmanan, 2011). In an increasingly globalizing world, such growth effects might arise through air transport connectivity, in particular.

While the economic effects of road transport are mostly investigated with respect to highway *infrastructure*, analyses on the economic effects of air transport are focused on the impact of air *services*. According to Button and Yuan (2013), for example, airfreight throughput fosters economic development. Various studies have also isolated significant increases in population and employment through passenger air transport (Brueckner, 2003; Green, 2007; Percoco, 2010). Additionally, Sellner and Nagl (2010) identify positive contributions of passenger throughput to output level and investments.

Although substantial aggregate impacts of air transport on economic activity have been identified, their scale and direction might differ among airports. In this paper, we analyze airports' capital stock and air service supply as potential drivers of these differences.

The paper proceeds as follows. In Section 2, we present our empirical approach. In Section 3, the results of the estimation are discussed. Section 4 concludes.

## 2. Empirical approach

### 2.1. Specification

Since Aschauer (1989), the economic impacts of public infrastructure have been analyzed with the help of production functions. In such models, public infrastructure $G_i$ can be considered as a determinant of multifactor productivity $A_i$. This yields Eq. (1).

$$Y_i = A_i(G_i)f_i(L_i, K_i) \tag{1}$$

where $Y_i$ is output of region $i$, $L_i$ labor input and $K_i$ the total capital stock. In line with this approach, we introduce the airport capital stock ($A.CAP_i$) to Eq. (1) as a subset of $G_i$. However, we do not exclude $A.CAP_i$ from $K_i$, but keep $K_i$ as the total capital stock including $A.CAP_i$. Following Canning (1999), the estimated impact of $A.CAP_i$ is only positive in such a model setup, if $A.CAP_i$ is more productive than $K_i$. 'Opportunity costs' of airport capital are therefore considered in terms of the yearly output from an alternative appropriation of airports' capital in the economy.[1]

Contrary to road transport, air transport is predominately scheduled transport. Thus, connectivity is not directly generated through air transport infrastructure but is dependent on air services being offered. We therefore introduce air service supply to Eq. (1) as well. In contrast to existing analyses (e.g. Brueckner, 2003), we prefer aircraft movements ($MOVE_i$) to passenger throughput as a metric for air service supply, since aircraft movements better reflect air service connections and are not biased by the capacity of operating aircraft and aircraft capacity utilization.

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[1] Note that our output-based metric of opportunity costs differs from definitions based on capital costs.

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Furthermore, one might assume that regions with well-established air transport links also invest in high road and rail connectivity.[2] Consequently, analyses on the economic effects of air transport might be biased, if connectivity metrics of other transport modes are not considered. Thus, we follow Percoco (2010) and introduce a surface transport metric ($INFRA_i$) to Eq. (1). This metric is derived from average travel time to economic centers and reflects connectivity,[3] which is generated though road infrastructure and scheduled rail services.

To specify the production function, we follow e.g. Boarnet (1997) and apply a Cobb-Douglas production function combined with a second-order specification of multifactor productivity.[4] To account for possible interdependencies between airport infrastructure and air traffic, we further include their cross product. This yields Eq. (2).

$$\begin{aligned}\ln(Y_i) = {} & 0.5\varepsilon_2\ln(A.CAP_i)^2 + 0.5\zeta_2\ln(MOVE_i)^2 \\ & + 0.5\iota_2\ln(INFRA_i)^2 + \kappa_{A,W}\ln(A.CAP_i)\ln(MOVE_i) \\ & + \sum_{i=1}^{N}\gamma_i D_i + \sum_{t=1}^{T}\delta_t Time_t + \alpha\ln(L_i) + \beta\ln(K_i)\end{aligned} \quad (2)$$

### 2.2. Data

A panel of 19 German airports[5] (Table 1) is used for the analysis. For each airport, we parameterize an "affected area" to estimate Eq. (2). In previous analyses, such "affected areas" consisted of the administrative region, which the airport is located in (Brueckner, 2003), and, in some cases, its neighboring administrative regions (Percoco, 2010). However, the spatial spread of output effects is not influenced by administrative borders, but rather by the geographical position of an airport and by the connectivity which is generated through airport access and the air services offered. Therefore, our 'affected areas' are parameterized by using a distance-criterion[6] and a connectivity-criterion.[7] If contours of affected areas overlap, we cluster airports and their affected areas since output effects cannot be apportioned to a particular airport (Table 1). Note that we consider affected areas only because this analysis aims at the identification of differences in the scale and direction of regional growth effects of air transport. Consequently, the analysis does not consider economic effects outside of our affected areas.

A dataset for the years 1997–2006 is used for the analysis. Data for the affected areas and airport clusters in each year are obtained by summing the data of related airports and counties respectively or by calculating the population-weighted mean of $INFRA_i$. The parameterization of all variables, their data sources and descriptive statistics are shown in Table 2.

### 2.3. Estimation

Panel unit root tests reveal evidence of our time series being integrated of order 1. Additionally, cointegration tests do not sufficiently support the presence of cointegration. Consequently, the estimation is conducted with first-differenced data to avoid spurious results.

Furthermore, reverse causality with respect to the variables of the transport system may bias estimation results. Thus, an instrument variable estimator is applied. The Limited Information Maximum Likelihood (LIML) estimator is preferred to the two stage least squares estimator since it is more robust to weak instruments. The population in the affected areas, the lagged relative importance of each airport for German air transport and lagged values of potentially endogenous variables are introduced as instruments. They are considered to be exogenous, because output variations cannot influence the population in an affected area directly.[8] In addition, a feedback from output variation in a certain period on a lagged, potentially endogenous variable cannot exist, so that lagged variables (in differences) are exogenous instruments. As instrument exogeneity ensures the estimation's validity, the Hansen *J*-test is applied. The test assesses the null hypothesis that instruments are uncorrelated with the error component and that they are rightly excluded from Eq. (2). In addition, we calculate the Kleibergen–Paap *F*-statistic to reveal potential weak instrument bias.

With respect to autocorrelation, we consider contemporary dependence and serial autocorrelation. While serial autocorrelation is not present, tests indicate the presence of contemporary dependence (Table 3). Thus, estimation procedures to account for arbitrary cross-sectional autocorrelation and heteroscedasticity are used.

**Table 1**
Airport clusters and airport types.

| Cluster | Counties in affected area | Related airports | Airport type[a] | Passengers 2008 (*in* 1000) |
|---|---|---|---|---|
| 1 | 54 | FRA | First-tier | 53467 |
| | | HHN | Third-tier | 3940 |
| 2 | 16 | MUC | First-tier | 34531 |
| 3 | 55 | DUS | Second-tier | 18151 |
| | | CGN | Second-tier | 10343 |
| | | DTM | Third-tier | 2329 |
| | | PAD | Third-tier | 1137 |
| | | FMO | Third-tier | 1571 |
| 4 | 11 | TXL | Second-tier | 14487 |
| | | SXF | Third-tier | 6638 |
| | | THF[b] | Third-tier | 279 |
| 5 | 15 | HAM | Second-tier | 12838 |
| | | LBC | Third-tier | 535 |
| 6 | 16 | STR | Second-tier | 9925 |
| 7 | 7 | HAJ | Third-tier | 5638 |
| 8 | 17 | NUE | Third-tier | 4270 |
| 9 | 9 | LEJ | Third-tier | 2457 |
| 10 | 10 | DRS | Third-tier | 1856 |
| 11 | 11 | BRE | Third-tier | 2486 |

[a] The classification follows von Hirschhausen (2004). We subsume fourth-tier airports under third-tier airports.
[b] Berlin-Tempelhof was closed in 2008.

## 3. Results

The estimation results are presented in Table 3. The model (Model 1) explains a significant share of output variation and the

[2] This is rightly assumed if regions appreciate well-established connectivity through all transport modes. In our data, correlation between (time-based) $INFRA_i$ and $MOVE_i$ (−0.51) supports this assumption.

[3] According to Geurs and van Wee (2004), connectivity is a measure of distance which assesses the degree of connection between points. Travel times can be regarded as such a distance measure.

[4] The second-order specification imposes fewer assumptions on the multifactor productivity function. However, the specification needs to be assessed (Section 3).

[5] Since consistent data is not available for foreign affected areas, airports close to borders are dropped.

[6] All counties within a 50 km radius are assigned to the affected area.

[7] Beyond applying the distance criterion, we add counties to affected areas if business travelers are able to join meetings at average European destinations on a day-trip. In line with Gutiérrez (2001), a 4 h one-way threshold is used.

[8] Immobility, which arises from the value of social ties (Belot and Ermisch, 2009), for example, may cause this. Granger causality testing supports this notion for our data ($p$-value ≈ 0.46).

**Table 2**
Data sources and descriptive statistics.

| Variable | Parameterization | Data processing | Source | N·T | Mean | St. Dev. |
|---|---|---|---|---|---|---|
| *Y* | GDP [€, *year 2000 price level*] | Price adjusted | Statistical Offices of Federal States | 110 | $130.2 \cdot 10^9$ | $118.9 \cdot 10^9$ |
| *L* | Labor force | Adjusted by hours worked | Statistical Offices of Federal States | 110 | 2345000 | 2077000 |
| *K* | Capital stock [€, *year 2000 price level*] | | Calculations based on Deitmer (1993) | 110 | $666.1 \cdot 10^9$ | $573.0 \cdot 10^9$ |
| *A.CAP* | Fixed assets valued through acquisition and production costs [€, *year 2000 price level*] | Price adjusted | Financial statements of airports | 110 | $1.6 \cdot 10^9$ | $1.7 \cdot 10^9$ |
| *MOVE* | Aircraft movements (count of arriving and departing aircraft; non-commercial traffic and training flights excluded) | | German Airport Association | 110 | 161000 | 145000 |
| *INFRA* | Average road and rail travel time to the nearest three economic centers in Germany and abroad | Index [2006 average = 1] | Federal Institute for Research on Building, Urban Affairs and Spatial Development | 110 | 0.76 | 0.08 |
| *POPULATION* | Population | | Statistical Offices of Federal States | 110 | 4873000 | 4637000 |
| *WLU_SHARE* | WLU Share of the Airport: Relative importance of airport/airport cluster for German air transport | | | 110 | 0.09 | 0.11 |

impacts of $L_i$ and $K_i$ are significant with the expected signs.[9] Additionally, the Kleibergen–Paap *F*-Statistic and the Hansen *J*-test indicate that instruments are sufficiently relevant and should not be considered endogenous.

Potential misspecification of Model 1 is assessed with the RESET approach (Ramsey, 1969) and with a log-log-specification of multifactor productivity (Model 2). Since the latter does not yield significant results and since higher-order transformations of expected output do not explain output (order-3 RESET *p*-value: 0.95), there are no signs for such misspecification.

We therefore use the results from Model 1 in the following sections to discuss potential differences in the economic effects of airports.

### 3.1. Effects of airport provision

Airport provision absorbs capital, which causes 'opportunity costs' in terms of output from an alternative appropriation of airports' capital in the economy. Since we consider these 'opportunity costs' (Section 2.1), we expect airport investments to, ceteris paribus, reduce economic growth.[10] From Eq. (2) and the estimation results for Model 1 in Table 3, Eqs. (3a) and (3b) are derived.

$$\frac{\partial \ln(Y)}{\partial \ln(A.CAP)} = 0.036\ln(A.CAP) - 0.066\ln(MOVE) > 0 \tag{3a}$$

$$\Leftrightarrow \frac{\ln(MOVE)}{\ln(A.CAP)} < 0.544 \tag{3b}$$

(3b) is not true for German first- and second-tier airports. This finding suggests that the mere provision of such airports is less productive compared to general capital appropriation because of the presence of 'opportunity costs' of capital. Thus, expansions of first- and second-tier airports might reduce economic growth, if no additional air transport connectivity arises.[11]

In contrast, German third-tier airports unexpectedly meet the criterion from (3b). Since third-tier airports absorb less capital from the economy, the declining 'opportunity costs' of capital at these airports may partly cause this result. Additionally, two effects potentially outweigh the small 'opportunity cost' of third-tier airports. First, companies might regard airport investments as an indication that regional policymakers support economic development by making locations attractive for companies. Thus, enterprises may be incentivized to move into the region or to enlarge business there. Second, flight schedules reveal that larger third-tier airports in the dataset offer more air services to hubs and other main economic centers. Thus, enhanced 'core connectivity' at larger third-tier airports potentially contributes to the result. Given the correlation between 'core connectivity' and the provision of third-tier airports, our results rather suggest that investments at third-tier airports need to be aligned with enhanced 'core connectivity' to facilitate economic growth.

### 3.2. Economic effects of air services

Air transport creates connectivity through scheduled air services. Therefore, we expect the output elasticity of air transport movements to be positive. From Eq. (2) and the estimation results for Model 1 in Table 3, Eqs. (4a) and 4(b) are derived.

$$\frac{\partial \ln(Y)}{\partial \ln(MOVE)} = 0.115\ln(MOVE) - 0.066\ln(A.CAP) > 0 \tag{4a}$$

$$\Leftrightarrow \frac{\ln(MOVE)}{\ln(A.CAP)} > 0.571 \tag{4b}$$

While (4b) is fulfilled for first- and second-tier airports, it is not true for third-tier airports. Thus, the marginal output effects of air services are positive for additional air services at first- and second-tier airports, whereas they are surprisingly negative for additional air services at third-tier airports. This finding might be explained with the prevailing traffic patterns at different airports. Traffic growth at German first- and second-tier airports is mostly catered to business travelers (Fig. 1). Such traffic may, ceteris paribus, increase economic growth, since it generates connectivity to destinations, which are attractive for economic interaction. By contrast, traffic growth at third-tier airports is mostly leisure-related (Fig. 1). Although leisure flights create private benefits, they do not foster connectivity through air services, which cater to business travelers. On the contrary, additional leisure-related air services might actually weaken a regional economy by diverting expenditures away. The latter is particularly important in Germany, since data provided to us by the German Aerospace Center (DLR) from their 2008 passenger survey finds that private outbound trips account for 81% of

[9] As $INFRA_i$ is based on travel time, a negative impact is expected.

[10] Note that a reduction of growth is considered equivalent to an acceleration of recession.

[11] If an expansion eradicates infrastructure bottlenecks, improvements of connectivity are expected. Such projects are discussed in Section 3.2.

**Table 3**
Estimation results.

| $\ln(Y_i)$ | (1) | (2) |
|---|---|---|
| Period fixed effects | Yes | Yes |
| $\ln(L_i)$ | 0.697** | 0.703** |
| | (0.339) | (0.261) |
| $\ln(K_i)$ | 0.357* | 0.475** |
| | (0.216) | (0.191) |
| $0.5\ \ln(MOVE_i)^2$ | 0.115** | |
| | (0.036) | |
| $\ln(MOVE_i)$ | | −0.096 |
| | | (0.258) |
| $0.5\ \ln(INFRA_i)^2$ | −0.518 | |
| | (0.448) | |
| $\ln(INFRA_i)$ | | 0.201 |
| | | (0.134) |
| $0.5\ \ln(A.CAP_i)^2$ | 0.036** | |
| | (0.011) | |
| $\ln(A.CAP_i)$ | | −0.039 |
| | | (0.121) |
| $\ln(A.CAP_i)\ \ln(MOVE_i)$ | −0.066** | 0.003 |
| | (0.020) | (0.012) |
| $F$ | 6.26 | 6.66 |
| $R^2$ | 0.443 | 0.449 |
| Serial Autocorrelation $p$-value[a] | 0.800 | 0.620 |
| CD-Test ($p$-value)[b] | 0.105 | 0.527 |
| Kleibergen–Paap $F$-Statistic[c] | 5.151 | 6.208 |
| Hansen $J$-statistic ($J \sim \chi^2_2$) | 3.412 | 3.382 |

$^*p < 0.1$.
$^{**}p < 0.05$.
[a] Null hypothesis of the serial autocorrelation-test is no first-order autocorrelation.
[b] Null hypothesis of the CD-test is cross-sectional independence.
[c] Critical values are 4.72 (LIML) or 16.87 (TSLS).

private air transport at German airports and, by far, exceeds private inbound trips (19%).

According to these results, the contribution of airports to economic development depends on the supply of air services, which cater to business travelers. Since we derive this finding from airports' prevailing traffic structures, we can assume that growth effects from increased air transport services would also be induced at third-tier airports if the additional traffic generates connectivity to destinations, which are attractive for economic interaction.

Beyond that, our results reveal that capacity bottlenecks or administrative restrictions on the utilization of airports potentially entail an economic cost, if they constrain the supply of air services. Therefore, expansions of capacity-constrained airports might promote economic growth if the positive output effects from additional air services outweigh the negative effects of capital appropriation (Section 3.1).

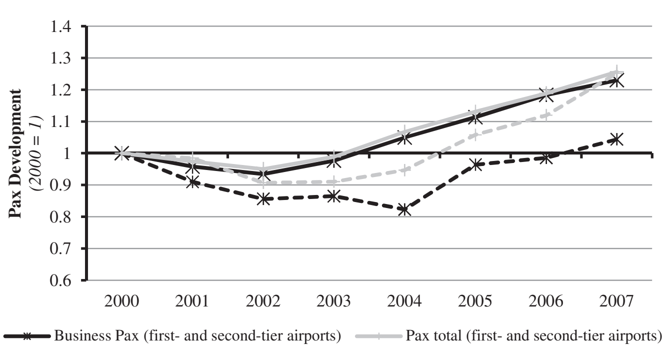


**Fig. 1.** Traffic development at German airports.

## 4. Conclusions

In this paper we have presented empirical evidence that the output effects of air transport differ significantly among airports. We attribute this to the existence of 'opportunity costs' of capital appropriation at airports and to different traffic characteristics with respect to air transport connectivity.

While we explain some results with different traffic patterns, these traffic patterns are not directly captured in our model. This is an important caveat of our approach. Future research should therefore try to incorporate information about traffic characteristics. Analyses, which consider air transport connectivity through transfer traffic, might be helpful in this respect (IATA, 2007). However, more detailed accessibility measures (e.g. Matisziw and Grubesic, 2010) should be employed for that purpose.

We close by stressing that cut-off criteria have been applied for the parameterization of affected areas in our analysis. Although we regard our approach as an improvement compared to parameterizations based on administrative borders, the actual spatial scope of the growth effects of air transport remains unexplored. The geographical size of airport catchment areas (Lieshout, 2012) may provide some guidance in this respect. However, the possible presence of demand-side spillover effects and non-use values indicates the need for further research. Since public entities are still important shareholders of airports, this is particularly important for realizing fiscal equivalence between airports' beneficiaries and financiers.

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